# A High-Clearance Self-Propelled Sprayer for Sweet Corn



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U. S. DEPARTMENT OF AGRICULTURE

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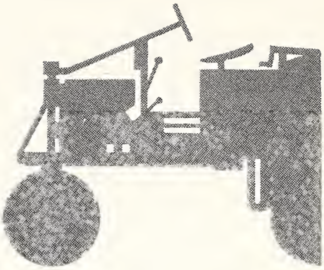

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## INTRODUCTION

Recent increases in number and variety of insects attacking sweet corn, and the higher standards of purity now established for the canned product, have caused commercial growers to focus their attention on development of high-clearance equipment for effective application of insecticides to this crop.

According to regulations established under the Federal Food, Drug, and Cosmetic Act, no insect contamination is tolerated in canned or frozen corn. In view of present infestation levels of such insects as the European corn borer (*Pyrausta nubilalis* Hbn.), corn earworm (*Heliothis armigera* Hbn.), fall armyworm (*Laphygma frugiperda* A. & S.), and Japanese beetle (*Popillia japonica* Newm.), canners may well be greatly concerned over the possibility that large quantities of their corn will be destroyed by insects and that parts of their annual corn pack will be seized because of insect contamination. For effective application of insecticidal material to sweet corn at any stage of growth without stalk breakage, specially designed high-clearance self-propelled equipment is necessary. Boom and nozzle design must be such as to direct the insecticide, with a minimum of waste, to areas of the plant where it can give best results. Because of types of terrain on which the corn is grown, the equipment not only must have adequate power and traction but, for safe operation, must be highly stable. Development of such equipment should be an important factor in reducing the present corn losses and contamination.

Work on development of a high-clearance self-propelled sprayer for sweet corn was begun by the United States Department of Agriculture in cooperation with the Maryland Agricultural Experiment Station in 1949. The work involved design and construction of an experimental sprayer and extensive field testing of it over a period of 2 years. During 1950 a related commercial-scale spraying experiment was carried on with the cooperation of two Maryland canners. Two objectives of this experiment were (1) to get information on the cost of the insecticidal treatments and (2) to get information on comparative costs of trimming heavily infested and lightly infested corn.

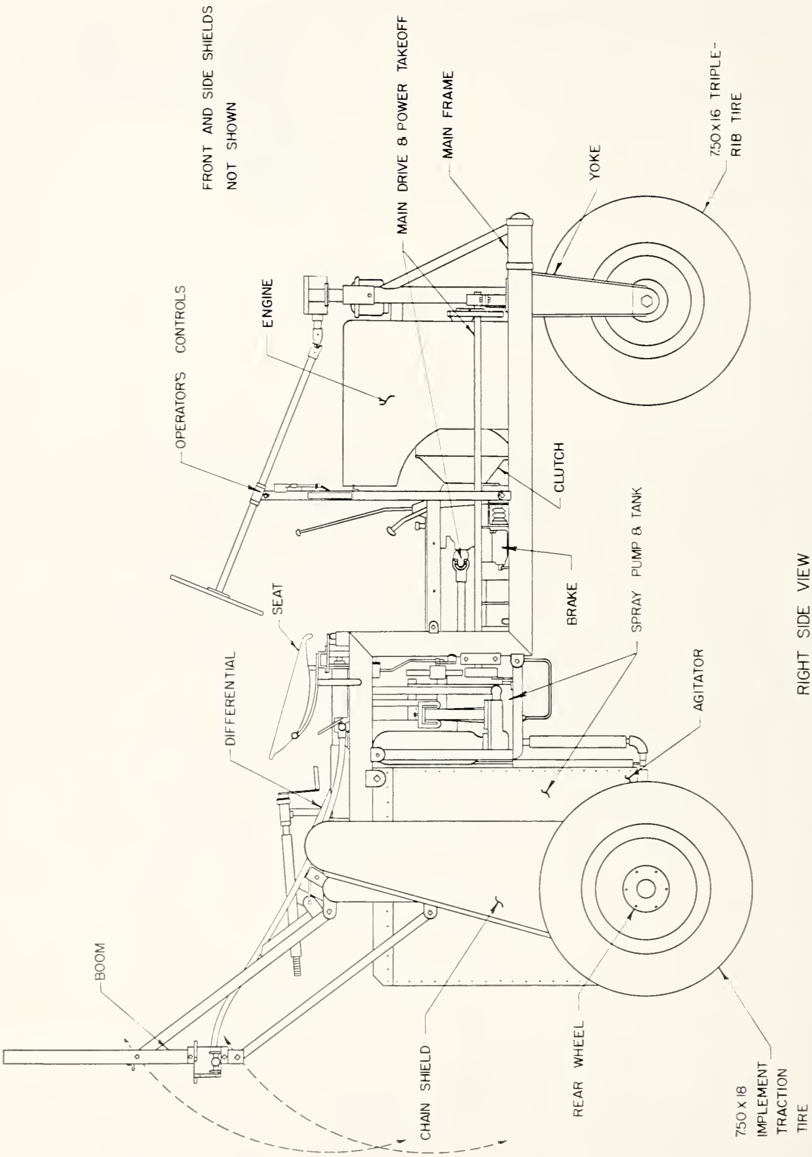


FIGURE 1.—Assembly drawing of high-clearance self-propelled sprayer for sweet corn.

## PROPOSED SPRAYER SPECIFICATIONS

After a thorough study was made of the equipment problems and mechanical requirements, the following specifications were proposed for a high-clearance sprayer suitable for operation on all types of cornfield terrain but especially on rough and hilly types such as are found in the East:

General.—Three-wheeled, high-clearance, 6- to 8-row coverage, convertible from spray to dust if necessary, low center of gravity for stability on grades, ease of transport.

Drive.—Two-rear-wheel drive to obtain maximum traction without losing stability, powered by lightweight, compact engine with sufficient power to propel machine under all conditions, transmission with 3 forward speeds and 1 reverse, foot-operated automotive-type clutch, brakes located on rear wheels.

Frame.—Clean, simple appearance, ability to carry heavy loads of insecticidal material, operator's seat and controls easily accessible, unobstructed vision, clearance suitable for sweet corn, tread suitable for 36- to 42-inch row spacing.

Spray unit.—Completely removable, tank of galvanized sheet steel with 100-gallon minimum capacity and equipped with mechanical agitation, reciprocating-piston-type pump of 7-gallon-per-minute capacity and powered by main engine but independent of main-drive clutch, boom adjustable in height and adaptable to different types and numbers of nozzles.

## CONSTRUCTION OF EXPERIMENTAL SPRAYER [1]

On the basis of observation and testing of other spraying equipment, an experimental high-clearance sprayer was designed (fig. 1) and built in accordance with the proposed specifications. Special emphasis was placed on using standard commercial parts and materials wherever practical, and construction practices were limited to those for which the average machine shop is equipped.

The main frame of the sprayer is a welded unit made up of seamless steel tubing with lugs and angles for the attachment of the other parts. Stepdown design, from rear to front of the center parallel frame, provides several desirable features: The spray tank and pump unit are readily and simply suspended from the higher part of the parallel frame at the rear; mounting the engine power unit above the low part of the frame at the front provides a relatively low center of gravity; and the front-wheel yoke—a welded unit—and the steering column are provided with a rigid support. Bronze radial and thrust bearings plus a conventional-type steering gear provide adequate ease of turning. A relatively large front tire with triple-rib tread is used, to hold the machine in line and reduce side slip. This type of tire

[1] For detailed plans of construction for this sprayer, see Black, D. T. high-clearance self-propelled canning corn sprayer. U. S. Bur. Plant Indus., Soils, and Agr. Engin., Divs. Agr. Engin. Inform. Ser. 103, 22 pp., illus. 1951. [Processed.]

also facilitates operation on soft ground or in crossing ridges and gullies. The machine has a 60-inch row clearance.

The rear driving wheels have standard hubs, hydraulic brake assemblies, and traction-tread tires. Large sprockets for $\frac{3}{4}$-inch-pitch roller chain, bolted to the hubs, are driven by small sprockets on the axle of a converted automotive rear-end assembly with differential gears, located on top of the main frame. Power from a 12-horsepower, 2-cylinder, air-cooled engine is transmitted through an automotive-type clutch and 3-speed transmission to steel-cable V-belts, which carry it vertically to the drive shaft of the rear-end assembly. Power to drive the spray pump is supplied by the same engine, through a takeoff shaft driven from the front of the engine crankshaft. This unit is independent of the main-drive clutch—a feature that is very important with regard to maintaining a constant pressure in the spray system. There is a simple belt-tightening clutch between the pump and the takeoff shaft, which has a simple control easily accessible to the operator.

A 2-cylinder reciprocating pump (fig. 2) rated at 7 gallons per minute and 400 pounds per square inch at 70 revolutions per minute was selected for its lightness and resistance to corrosion and abrasion. It is equipped with an air chamber and high-pressure regulator. A bypass through a control valve to a low-pressure regulator provides a wide range of accurately controlled spray pressures.

The spray tank has a capacity of 150 gallons (one of 110-gallon capacity was used in the first year's tests) and is provided with a mechanical agitator in the form of a shaft with 4 paddles driven

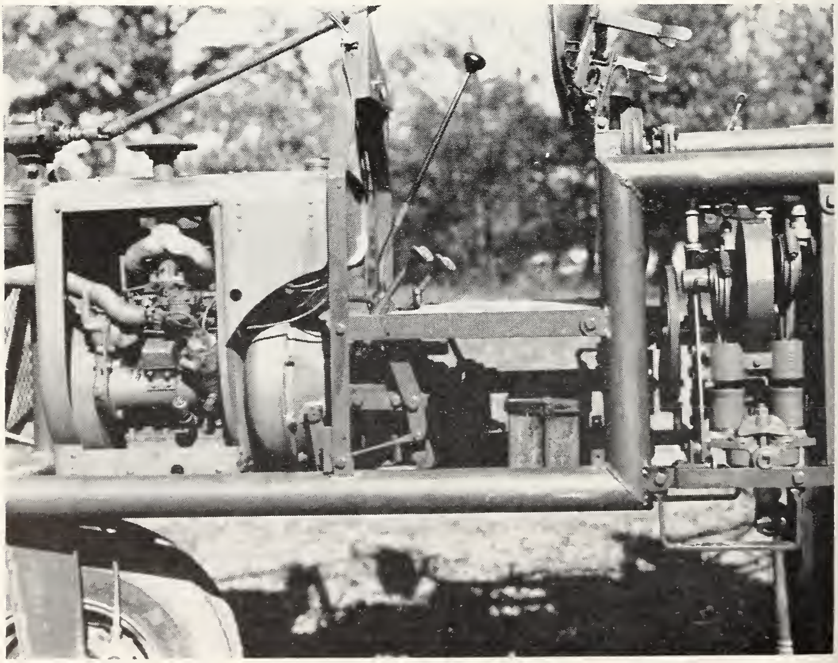

FIGURE 2.—Left side view of spray pump and main power train.

by chain and sprocket from the pump. A return line from the 2 pressure regulators adds to the agitation. The tank itself is made of 18-gage galvanized sheets riveted together and soldered at the joints. Baffles are provided for strength and dampening effect. The entire top of the tank can be unbolted and removed, to make cleaning easier. A filler opening fitted with a removable screen is provided in the cover.

The boom design of the experimental sprayer follows closely the recommendations of Blanchard.[2] Because the sprayer was intended for use on rolling terrain, the boom was designed to cover only six rows (fig. 3). Eight-row coverage would be advisable for a sprayer

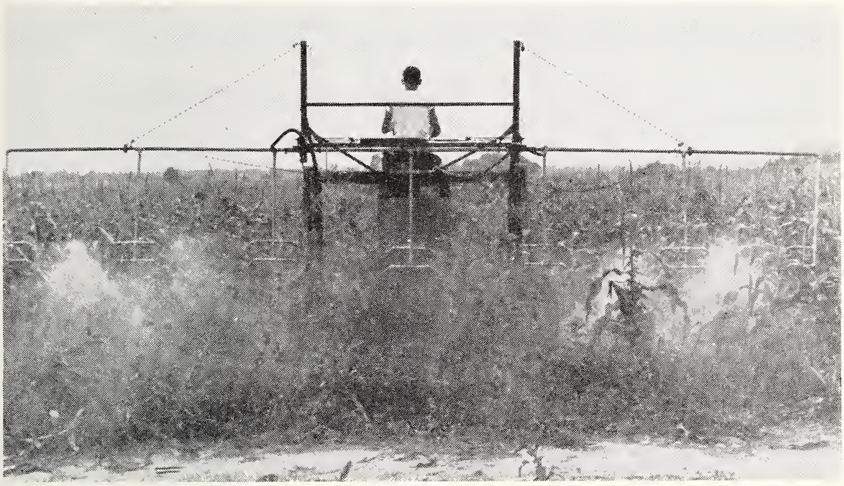

FIGURE 3.—Rear view of high-clearance sprayer with 6-row boom designed for coverage of ear zone of sweet corn.

to be operated on level ground. The boom can be adjusted vertically to a maximum height of 80 inches by means of parallel links operated by a screw crank from the driver's seat. Spring-loaded hinges permit either forward or rear folding of the boom extensions and serve as safety devices if obstacles are encountered. The boom extensions may also be raised to a vertical position when the sprayer is to be turned or transported. Rigid drop feed lines 28 to 30 inches long are placed on the boom at 42-inch intervals. This spacing permits suspending the feed lines between the corn rows at intervals the same as the standard row intervals. Where row spacing is less than 42 inches, the operator angles the boom extensions forward. Four narrow-angle flat spray nozzles are used per row. All spray-line piping with the exception of rubber hose connections is galvanized. The nozzles are tipped with stainless steel.

The nozzle pattern was designed primarily for corn earworm control. The earworm feeds in the ear under the protection of the husks, away from parasites and predators and inaccessible to insecticidal

[2] BLANCHARD, R. A., DOUGLAS, W. A., WENE, G. P., and WOOTEN, O. B. DDT SPRAYS FOR CONTROL OF THE CORN EARWORM AND THE BUDWORM IN SWEET CORN. U. S. Bur. Ent. and Plant Quar. E-780. (Revised.) 1951.

treatments. Insecticides applied superficially to the tip of the ear and the silk have never provided an effective barrier to entry of the young earworm larvae under conditions of heavy infestation. To be effective against this pest, an insecticide must be applied in such a manner that it penetrates the silk channel. Earworm sprays are applied not to the entire plant but only to the ear and adjacent parts. The nozzles on the experimental sprayer are carried on the drop feed pipes in such a way that they apply the spray in a rather narrow band. The upper nozzles on the boom drops are about 5 inches above the lower, and all nozzles are about 7 inches from the feed line. The nozzles are directed downward at an angle of approximately 35°, so that the spray is driven down into the ear and plant. The upper nozzles are directed slightly forward and the lower nozzles slightly backward.

The operator's seat is situated so that he has an unobstructed view of the row and the boom. All controls are within easy reach. A direct-driven speedometer is provided to aid in maintaining a constant rate of travel, which is an important factor in maintaining a correct rate of insecticide application.

## TESTING OF SPRAYER

Testing of the experimental high-clearance sprayer under all types of field and weather conditions was carried on in Maryland during two seasons, those of 1950 and 1951.

The first summer's testing was conducted on the Eastern Shore of the State, where the terrain is of a gently rolling type. The sprayer proved to be stable at all times even on rough and hilly ground. Availability of adequate power was evidenced by the sprayer's ability to climb over hummocks and out of ditches. Traction was adequate for all types of soil conditions encountered. The fields sprayed averaged about 8 acres but ranged from 3 to 19 acres. Most of them were irregular in shape and therefore had uneven row lengths. On some fields, low-hanging tree branches and narrow headlands made turning difficult. In some cases it was necessary to fold one of the boom extensions while turning. The row spacings encountered averaged 40 inches. By angling the boom extensions forward, good spray coverage was obtained on rows spaced as closely as 36 inches.

On an average, a speed of 4 miles per hour was maintained in spraying. On large, level fields the speed was increased to 4½ miles per hour. Speeds higher than this made steering so difficult that they could not be maintained for any extended period. In some fields, in order to maintain complete coverage, the operator had to change the elevation of the boom several times, while moving. He did this very easily and quickly. The machine's 60-inch row clearance proved adequate for all the yellow corn sprayed. Even though the white corn averaged 8 feet in height, in comparison with 5 feet for the yellow corn, there was no evidence of any stalk breakage in it due to the machine. Also, there was no evidence of any effect of the machine's clearance on the spray coverage. The operator found the sprayer very easy to handle under all normal conditions. Visibility of pressure gages, speedometer, boom, nozzles, and rows to the operator was very good, and the operator's seat and the controls were easily accessible (fig. 4).

Only one major change was made in the machine on the basis of

the first year's experience—a spray tank of 150-gallon capacity was substituted for the original 110-gallon tank in order to reduce the frequency of refilling.

Field testing during the second summer was carried on chiefly in the central part of Maryland, on severe terrain. In general, the terrain encountered represented some of the hilliest and roughest areas used commercially for growing sweet corn in Maryland—or, possibly, anywhere else. The sprayer, however, proved again to be entirely stable at all times and had sufficient power to maintain a constant rate

FIGURE 4.—Treating sweet corn at the silking stage. Note the visibility of rows and controls to the driver and the accessibility of the controls.

of travel. Manual adjustment of the otherwise automatic (governor-controlled) throttle was necessary at times on the steeper grades. The steepest grades encountered were 21 percent in the direction of travel and 30 percent across the row. On the steepest cross grades, some difficulty was experienced in keeping the machine in the row and only the triple-rib design of the front tire made controlled steering possible. This tire design also made steering easier when it was necessary to ride cultivator ridges in the row. The large size of the sprayer's rear tires proved advantageous in climbing over ridges and out of wash gullies.

Very little trouble was experienced during either season with clogging of nozzles or lines. This can be attributed mainly to the use of emulsions for the insecticidal spray and partly to the use of small-mesh suction- and pressure-line strainers. Special care was taken in cleaning the tank and lines after each day's spraying. A thorough check of the spraying equipment at the end of the season revealed no signs of corrosion. Comparison of before-season and after-season discharge rates of the stainless-steel-tipped nozzles used showed little or no change in orifice size due to the spray materials.

Because of the constant jarring caused by rough and hard ground, there was some breakage of boom drops. Constructing them of extra-heavy pipe extended their life considerably.

## APPROVED SPRAYER SPECIFICATIONS

General description.—Tricycle type, 2 rear drive wheels, single-front-wheel steering, single engine for traction and spray pump, tubular frame, rear frame and wheels straddle 2 rows, clearance over rows 60 inches, wheel base 88 inches, tread of rear wheels 84 inches.

Center-of-gravity location.—Tank empty and without driver, 33.0 inches forward of rear axle and 39.2 inches above ground level. Tank full and 155-pound driver, 18.1 inches forward of rear axle and 42.7 inches above ground level.

Weight.—Tank empty and without driver, 2,280 pounds. Tank full and with 155-pound driver, 3,676 pounds.

Engine.—Two-cylinder, air-cooled power unit, rated 13 horsepower at 2,400 r. p. m.

Clutch.—Automotive-type, spring-loaded, 8½ inches.

Transmission.—Three forward speeds, one reverse, maximum road speed 11 m. p. h.

Differential.—Automotive-type, converted.

Tires.—Front, 7.50 x 16 triple-rib; rear, 7.50 x 18 implement-traction.

Brakes.—Hydraulic, automotive-type, on rear wheels, foot-pedal control.

Power takeoff.—From front of engine, belt-driven shaft, belt-tightening-type clutch.

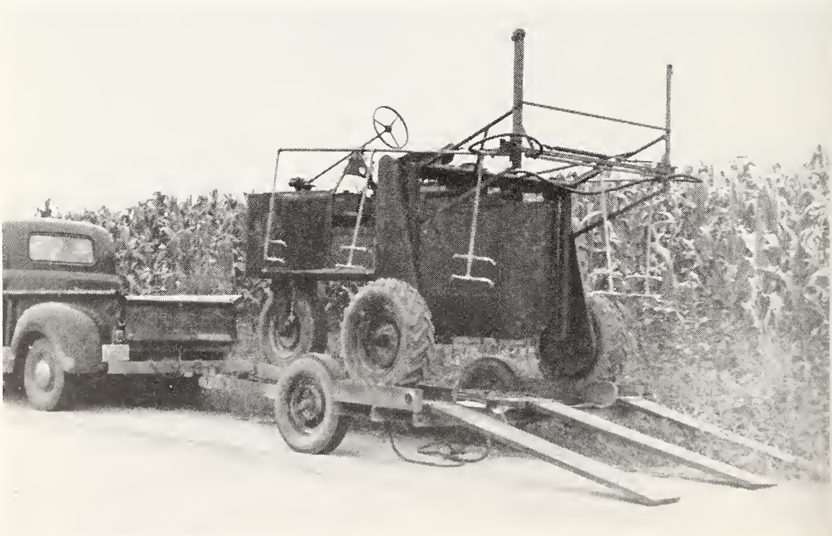

Figure 5.—Specially designed low-bed trailer for transporting sprayer from field to field.

PUMP.—Duplex, capacity 7 gallons per minute at 70 r. p. m. and 400 p. s. i.

HIGH-PRESSURE REGULATOR.—Unloading-type, range 0–400 p. s. i., adjustable.

LOW-PRESSURE REGULATOR.—Diaphragm relief-type, range 0–125 p. s. i., adjustable.

TANK.—Capacity 150 gallons, width 23 inches, length 44 inches, depth 38 inches, with semicylindrical bottom, material 18-gage galvanized sheet iron, clearance 16½ inches above ground.

AGITATOR.—Four 2-bladed paddles, 3 inches wide and 4-inch tip radius, driven by chain from pump, 120 r. p. m.

STRAINERS.—Tank-filler strainer, 20-mesh screen; suction-line strainer, 50-mesh; pressure-line strainer, 50-mesh.

SPRAY BOOM.—Six-row coverage, vertical adjustment by parallel links operated by screw crank from driver's seat, boom side extensions raised by ropes and pulleys to vertical for turning or transporting, spring-loaded hinges for either forward or rear folding, self-returning to operating position.

## FACTORS IN EFFICIENCY OF SPRAYING OPERATION

In making a study of the overall spraying operation from an engineering standpoint, it was found that several correctable main factors limited the speed of operation or the acreage that could be treated with one machine. In the commercial-scale spraying experiment carried on during 1950, most of the fields of each canner were within a 5-mile radius of the canning plant but the timing order of spray application was such that it was necessary to travel 2 to 3 miles on an average and in some cases as far as 15 miles between two fields treated consecutively. As the sprayer's maximum road speed was restricted to 11 miles per hour for safety reasons, it was more practical to use a specially constructed low-bed trailer equipped for fast loading (fig. 5). The sprayer was quickly and easily tied down to the trailer with load binders. This trailer was used during both seasons, and the amount of time thus saved was appreciable.

It was found that a spraying crew of 2 men was adequate—1 man to operate the sprayer and 1 to keep spray material ready for quick refilling.

During the second season, an effort was made to reduce the time required by the actual spraying operation. A 900-gallon tank was procured and mounted on a platform truck. An agitator was installed for mixing and maintaining the spray material. A small gasoline engine powered the agitator, and a 50-gallon-per-minute centrifugal pump was used for transferring the insecticide to the sprayer in the field. This pump was so connected that, by manipulating valves, materials could be moved into or out of the mixing tank at high rates. Water for refilling the nurse tank was usually available from a water tower at the canning plant. In an emergency, it could be pumped in. The insecticide used in the second year came as a proprietary product, containing mineral oil and DDT emulsion, which was diluted at the rate of 1 part stock to 9 parts water. By using 1 drum of the stock,

a load of 540 gallons was made at one time. One man, using the nurse-truck pump for moving the stock from drum to tank, could make the transfer rapidly from ground level, with no lifting. Use of the nurse truck containing premixed spray material reduced from 9 to about 4 minutes the time required for a complete refill in the field. It also eliminated the necessity of calculating fractional sprayer loads in the field, a problem that otherwise arises whenever the sprayer tank must be replenished without having been completely emptied.

Several fields of only 3 to 5 acres each were treated during the first season. The high ratio of preparation-for-spraying time to actual spraying time in these cases makes the economic feasibility of treating such small fields debatable. If a canner's entire acreage were made up of small fields such as these, the maximum acreage treated per day would not be more than 30. On the other hand, where fields average 30 to 40 acres it would be possible to cover between 60 and 70 acres per day.

For effective control of insects by spraying, the applications must be timed accurately. Even though plantings of sweet corn are usually staggered, weather conditions sometimes cause an excessive acreage of the corn to become ready for treatment at one time. Darkness restricts the working day. The only answer that has appeared is equipping the sprayer with lights for night operation.

## COMMERCIAL-SCALE SPRAYING EXPERIMENT

The commercial-scale spraying experiment carried on during the 1950 season was set up on the hypothesis that the cost of controlling the European corn borer would be offset by greater efficiency of plant operation if the treatment used to control the corn borer were one effective also against the earworm, fall armyworm, and Japanese beetle. The level of corn borer infestation in Maryland, with few exceptions, has not been high enough to cause appreciable corn losses. The borer is of importance in the State, however, as a contaminant of the canned product. The cost of any insecticidal program effective against the corn borer alone must be looked upon as insurance against condemnation and loss of the canned product.

Although there have been isolated instances in Maryland of severe damage by the European corn borer and the corn earworm at the prevailing levels of infestation, the per-acre tonnage of sweet corn produced in the State is not expected to be increased appreciably by control of these insects. The fall armyworm, however, often does great damage late in the season, and its control results in definitely increased tonnage yield. Sweet corn is generally planted early enough to escape whorl-stage injury by the fall armyworm, but this insect often destroys late-market corn before it reaches the tassel stage and often does considerable damage to the ears. Usually canners fail to recognize the fall armyworm and attribute any ear injury done by it to the earworm.

One of the canners who cooperated in carrying out this experiment used two home-built high-clearance tractor sprayers. His fields were located at Ridgely, Md. The Department of Agriculture sprayer was used on the second canner's fields, at Easton, Md.

The spray formulation used in these operations, as in all the other testing, was a mixture of 30-percent DDT emulsion, white mineral oil, and water, following closely the recommendations of Blanchard.[3] This was applied at a per-acre rate of 30 to 35 gallons where only 1 treatment was given and 26 to 28 gallons where 2 treatments were given. Spray pressures ranged from 80 to 120 pounds per square inch.

The first canner furnished all labor, equipment, spray material, and fuel and kept an accurate record of expenditures. He bought white mineral oil at $0.50 per gallon and 30-percent DDT emulsion at $2.00 per gallon. The treated area totaled 735 acres. A single application at the rate of 34.6 gallons per acre was given to 487 acres, and 2 applications at the rate of 26.3 gallons per acre each were given to 248 acres. The canner summarized his costs for the spraying operation as follows:

| | |
|---|---|
| Overall cost: | |
| Depreciation of equipment [1] | $756.50 |
| Truck hire | 210.50 |
| Fuel | 61.30 |
| Labor | 765.84 |
| Insecticide | 2,737.00 |
| Total | 4,531.14 |
| Cost broken down on basis of acreage and yield: | |
| Average cost per acre application | 4.60 |
| Average insecticide cost per acre application | 2.78 |
| Labor and overhead cost per acre application | 1.82 |
| Average cost of operation per ton of corn | 1.54 |

[1] The original cost of the sprayers is to be written off over a 5-year period.

The insecticide treatment was more effective against the earworm if given when the earworm infestations were comparatively high, at the beginning and at the end of the corn season, than if given at midseason. In individual late fields, 90-percent reduction of earworm was obtained with 2 sprayings. A considerable acreage of midseason corn was sprayed at Ridgely. The earworm infestation was low, and these treatments did not prove to be very effective. Unless the spray treatment is intended primarily for Japanese beetle or corn borer control, it should not be given when earworm infestation is expected to be below 40 percent.

When earworm infestation is less than 60 percent, a single properly timed application appears to be about 75 to 80 percent as effective as 2 properly timed treatments.

On fall armyworm, it appeared, the timing of spray applications could be varied more widely without greatly reducing the kill. All treatments, whether of 1 or 2 applications, gave excellent control of fall armyworm, usually exceeding 98 percent. Observations on control of the European corn borer at Ridgely were limited to one badly infested field. Unsprayed corn had an ear infestation of 16.9 percent; the part of the field that had received 2 treatments showed an infestation of 1.5 percent, more than 90 percent less. At Easton, corn

[3] See footnote 2, p. 5.

borer ear infestations never exceeded 3 percent in either treated or untreated fields. In some areas considerable Japanese beetle infestations were encountered. Earworm treatments are timed perfectly for control of the Japanese beetle and are 100-percent effective against the beetle.

Maturity probably influences cutoff, or yield in cases of canned corn per ton, more than any one other factor. As maturity could not be held constant, accurate determinations of the effect of insect injury could not be made. Late-season fall armyworm-earworm infestations were observed, in unsprayed fields, that were certainly causing a loss of 10 cases of corn per ton, but these were extreme conditions. Earworm infestations such as normally occur at the beginning of and in later parts of the canning season probably cause loss of 1 to 4 cases per ton of the raw product.

Complete daily records were obtained of the second canner's operation. Data on fall armyworm-earworm infestation and on cutoff in cases of No. 2 cans per ton for about 80 acres of white corn are given in table 1. These appear to be the most dependable observations made during the season, because all of this crop was handled during a period when labor and plant operations were normal and constant. The sprayed corn came in first; on the last day, only unsprayed corn was received. The lowest yield per ton, 17.9 cases, was obtained from unsprayed corn with the highest infestation, and the highest yield per ton, 29.3 cases, from sprayed corn with the lowest infestation.

Table 1.—*Level of earworm and fall armyworm infestation, rate of packing, and cutoff per ton of raw product for sprayed and unsprayed white corn from about 80 acres at Easton, Md., packed on 4 days of the period August 25–31, 1950* [1]

| Day of August | Ears infested | Cases of No. 2 cans packed per hour | Cases of No. 2 cans per ton |
|---|---|---|---|
| | *Percent* | *Number* | *Number* |
| 25 [2] | 33.1 | 325 | 22.1 |
| 26 [2] | 22.4 | 319 | 29.3 |
| 28 [2] | 36.5 | 306 | 24.5 |
| 31 [3] | 62.4 | 226 | 17.9 |

[1] The rate-of-packing value tabulated for each day is based on the full day's run, which on Aug. 25 and 31 included both white and yellow corn; all other values are for white corn only. The average infestation for the full day's run on Aug. 25 was lower than that tabulated; the run included 2 fields of sprayed yellow corn with 16.7- and 25.7-percent infestations. The average infestation for the full day's run on Aug. 31 was higher than that tabulated; the run included 2 fields of unsprayed yellow corn with 76.8- and 83.3-percent infestations and part of 1 field of sprayed yellow corn with 16.5-percent infestation.

[2] All material handled on this date had been sprayed.

[3] None of the white corn handled on this date had been sprayed.

The amount of trimming necessary was found to be much less when earworm and fall armyworm infestation was light. At Easton, on August 8, 1950, when the earworm and fall armyworm infestation

averaged about 10 percent, 15 tons of corn was trimmed per hour at a cost of $1 per ton; on August 29, when the infestation averaged 53.2 percent, 8 tons of corn was trimmed per hour at a cost of well over $2 per ton. Near the end of the season, heavy earworm and fall armyworm infestation was evident on the unsprayed corn at the Ridgely plant. There were 35 trimmers on the line, and 35 more were needed but not available. In the last part of the season, 20 trimmers were on the line, working on sprayed corn, and they were sufficient. The extent to which trimming labor can be reduced will depend on the minimum of labor needed at the time when maximum damage occurs. Personnel cannot be hired and dropped at will. Without an effective insect-control program, a canner may have to carry an excess of trimmers over more than half the season to be assured of adequate help when larval infestations are high.

Probably the greatest benefit derived from an insect-control program is the increase in plant output per unit of operation time (table 1). This increase, of course, results from more rapid handling of corn by trimmers and increase in cutoff per ton. On one occasion toward the end of the season, sprayed corn was delivered to the Easton plant in the morning and unsprayed corn in the afternoon. Plant output per hour was less by half while the wormy corn was being handled. To what extent worm injury can slow down cannery operation depends on the facilities and labor provided for trimming injured corn. Usually these facilities are limited, and when infestation goes beyond a certain level there is a reduction in plant output. At Easton, this critical level appeared to be about 40 percent.